

**APPLICATION**  
**FOR**  
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**TITLE: IMAGE ILLUMINATION OPTIMIZING**

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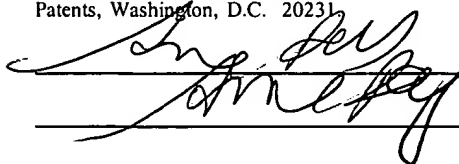
  
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IMAGE ILLUMINATION OPTIMIZING

5                   Background of the Invention

The invention relates to displaying images generated by a camera, and, in particular, to images generated by an electronic camera attached to a medical viewing instrument.

10           In general, medical viewing instruments, such as endoscopes, are instruments for viewing the interior of an object, such as the human body. For example, during a surgical procedure, an endoscope is inserted into the body to view an internal organ or anatomical body passage, such as the intestine.

15           A typical endoscope includes an elongated outer tube within which a lens system is disposed at a distal end. Light reflected from the object being viewed travels through the lens system and exits at a proximal end of the tube for viewing by a user either directly or via an imaging device,  
20           such as an electronic camera having a charge coupled device (CCD). The camera generates a video signal that represents the optical image of the object being viewed with the endoscope. The video signal generated by the camera is processed and displayed on a display device, such as a  
25           Cathode Ray Tube (CRT) Monitor.

          In applications where a camera is used, a coupler having a zoom lens assembly may be positioned between the endoscope and the camera. The endoscope/coupler combination, in essence provides an endoscope with zoom  
30           capability.

Summary of the Invention

The invention features controlling the brightness of an actual image produced by an image sensor (e.g., CCD) of an electronic camera, in response to the actual image area

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of the actual image occupying a total area of the image sensor. In particular, electrical signals generated by the electronic camera and representative of the size of the actual image area are used to control an electronic shutter  
5 associated with the camera. The electronic shutter is generally of the type used to control the duration of time the image sensor is responsive to light incident on the image sensor.

In a general aspect of the invention, an apparatus  
10 includes image size detection circuitry, which responds to electrical signals received from the electronic camera. Based on the signals, the image size detection circuitry determines an actual image area within a total image area of the image sensor, and generates a control signal, based on  
15 the actual image area, for controlling the electronic shutter.

In another aspect of the invention, the above-described image size detection circuitry is part of a medical instrumentation system including a medical viewing  
20 instrument (e.g., an endoscope) and the electronic camera optically coupled to the medical viewing instrument. The medical viewing instrument is used to view an object under observation. The image size detection circuitry is used to determine the actual image area within the total image area  
25 of the image sensor, and to generate a control signal, based on the actual image area, for controlling the electronic shutter.

In still another aspect of the invention a method of controlling an electronic shutter used with an image sensor  
30 of an electronic camera includes the following steps. Electrical signals are received from the electronic camera. In response to the electrical signals, an actual image area within a total image area of the image sensor is

determined. Based on the determined actual image area, a control signal is generated for controlling the electronic shutter.

Controlling the electronic shutter on the basis of  
5 the actual image area rather than the total image area has numerous advantages. In particular, the shutter responds only to light incident on an area of the image sensor which more closely approximates the area of the actual image. With this approach, the contribution of darkened border  
10 areas (i.e., inactive areas) of the image sensor surrounding the active image area is minimized. Thus, when the actual  
a image is displayed on a monitor, the likelihood that <sup>the</sup> ~~the~~ image will be "washed-out" or glared is significantly reduced.

15 Furthermore, because the actual image area is determined on the basis of the electrical signals provided by the electronic camera itself, control of the electronic shutter can be performed automatically and in real-time. The ability to control the shutter in this manner also  
20 allows the electronic camera and image sensor to be used with a greater variety of viewing instruments, particularly medical instruments (e.g., endoscopes, borescopes, colonoscopes).

Embodiments of these aspects of the invention may  
25 include one or more of the following features.

The electronic camera includes a plurality of predefined electronic shutter response areas, each electronic shutter response area defining different portions of the total image area of the image sensor. The control  
30 signal generated by the image size detection circuitry selects one of the electronic shutter response areas. In essence, the image size detection circuitry is used to select one of several predefined electronic shutter response

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areas of the electronic camera that most closely approximates the size of the actual image. The image size detection circuitry is used with a processor and a memory for storing data associated with the predefined electronic shutter response areas of the electronic camera.

The electrical signals include a luminance component received by the image size detection circuitry to determine the portion of the total image area of the image sensor containing the actual image. The luminance component of the electrical signals from the electronic camera provides a reliable indication of the level of light incident on any portion of the total image area of the image sensor.

The image <sup>size</sup> detection circuitry includes a comparator, an integrator, and an analog to digital converter. The comparator receives the luminance component of the video signals and generates a first output signal representative of a portion of the total image area. That is, the first output signal indicates the presence of a portion of an actual image. The integrator receives the first output signal from the comparator and generates a second output signal representative of the actual image area. The analog to digital converter receives the second output signal from the integrator and generates a digital signal representative of the actual image area for selecting data associated with one of the plurality of predefined electronic shutter response areas stored in the memory.

These and other features and advantages of the invention will be apparent from the following description of a presently preferred embodiment, and from the claims.

#### Brief Description of the Drawings

FIG. 1 is a schematic representation of a medical instrumentation system suitable for controlling the brightness of an image produced by a CCD in a camera;

FIG. 2 is a schematic representation of the system of FIG. 1 showing the camera and camera control unit in block diagram form;

FIGS. 3a-3c illustrate medium, small and large electronic shutter response areas of the CCD, respectively;

FIG. 3d illustrates a central electronic shutter response area and a shutter response pattern encompassing a total image area of the CCD;

FIG. 4 is a block diagram representation of an image size detection circuit used in the system of FIG. 2; and

FIG. 5 is a flow diagram for the operation of the image size detection circuit of FIG. 4.

#### Detailed Description

Referring to FIG. 1, a medical instrumentation system 10 is shown for generating visual images from light received through a medical viewing instrument, for example, an endoscope 20, and, among other functions, controlling the brightness of the visual images. Endoscope 20 is of the type having an elongated, hollow insertion tube 26 extending from a handle portion 30 to a distal tip 28 (Fig. 2) of endoscope 20. Insertion tube 26 is shown here inserted through an incision 48 within a leg 46 of a patient to convey visual images of an observation or surgical site to an electronic camera head 44 optically coupled to handle portion 30 of endoscope 20 via a zoom lens coupler 24. A light source 22 for illuminating the observation site is connected to endoscope 20 through a light cable 34. Light from light source 22 travels through a fiber optic cable bundle (not shown) extending along the inner wall of

insertion section 26. The light illuminates the object (not shown) under observation within leg 46. Light reflected from the object is received by a lens assembly within insertion section 26 of endoscope 20. To control the  
5 brightness of the received visual images, system 10 regulates the exposure of an image sensor to light from endoscope 20.

Electronic camera head 44 receives the reflected light from endoscope 20 through zoom lens coupler 24 which  
10 is used by the physician to provide magnified images of the observation site. Zoom lens coupler 24 includes a housing 38 connected to a proximal end 32 of endoscope 20 and lens adjustment knobs 40, 42. Each knob 40, 42 rotates independently to move the lens elements of a zoom lens  
15 assembly 36 (Fig. 2). One example of a zoom lens assembly suitable for use with instrumentation system 10 is described in co-pending application serial number 08/741,027 entitled "Optical Coupler", assigned to the assignee of the present invention, and incorporated herein by reference.

20 Camera head 44 includes an image sensor, for example, a charge coupled device or CCD 74 (Fig. 2) which generates video signals representative of the received images received by CCD 74. The signals are conveyed, via a cable 54, to a camera control unit 16 where they are  
25 processed and, as will be described in greater detail below, used to control the brightness of the image produced by CCD 74. It is important to note that signals received by camera control unit 16 are "raw" or not fully processed, i.e., the video signal is not in a format that is compatible with  
30 monitor 18.

Referring to FIG. 2, camera head 44 also includes a  
a flat glass ~~lens~~ 70 through which reflected light passes to CCD 74 without magnifying or focusing the reflected light.

CCD 74 includes an array of photoelectric cells (not shown) that transduce the reflected light into individual electrical signals that camera control unit 16 receives and uses to generate a standard video signal.

5 Camera control unit 16 includes a processor 82 that, among other functions, operates an electronic shutter 72, and also includes an image size detection circuit 75 that provides a control signal to processor 82 that allows electronic shutter 72 to produce a visual image having  
10 optimized brightness. It is important to note that in this embodiment electronic shutter 72 is not a mechanical device positioned between CCD 74 and the light source for controlling the amount of light incident on the CCD. Rather, electronic shutter 72 is an electronic  
15 implementation (e.g., hardware, software, or both) which controls the duration of time the photoelectric cells of CCD 74 are responsive to light incident on the CCD.

Processor 82 additionally processes the signals received from CCD 74 into ~~several~~ separate video signal components, such as luminance and chrominance. These separate video signal components are processed and then recombined to form the fully processed video signal which is then sent to monitor 18 through cable 52 for display on monitor 18.

Electronic shutter 72 serves as a light regulator for controlling the brightness of a visual image 56 displayed on monitor 18. Visual image 56 may occupy all of an image display area 58 or, as shown, may occupy only a portion of the image display area 58. Electronic shutter 72 is the portion of processor 82 that electronically regulates the amount of light accepted by CCD 74. Specifically, electronic shutter 72 controls the light exposure of CCD 74 by controlling the light integration time of the



photoelectric cells of the CCD. Thus, electronic shutter 72 controls image 56 so that the image is sufficiently bright but not so bright as to appear washed-out or glared.

5 In normal use, the optical system of endoscope 20 is designed to convey images of objects at distal end 28 at a fixed image plane at proximal end 32 where images are viewed (i.e., the eyepiece or mount). However, when zoom lens assembly 24 is attached to endoscope 20 to magnify the images, the size of the image received by CCD 74 varies. In  
10 particular, when magnification is at a minimum (for example, when zoom lens assembly 36 is "zoomed out"), the image received by CCD 74 may occupy a small portion of total image area 94 of the CCD. On the other hand, with maximum magnification (for example, when zoom lens assembly 36 is  
15 "zoomed in"), the image may be larger than total image area 94 of the CCD. The photoelectric cells of CCD 74 form a total image area 94 that contains two subareas: a circular active image area 96 and a bordering inactive image area 98. The area of CCD 74 on which the image is incident is the  
20 active image area. The area of CCD 74 on which the image is not incident is the inactive image area 98. For example, as shown in Fig. 2, active image area 96 of CCD 74 occupies only a portion of total image area 94 of the CCD and inactive image area 98 occupies the remainder of total image  
25 area 94 of CCD 74.

Based on the images incident on total image area 94, CCD 74 produces electronic signals that are transformed by processor 82 into a video image on monitor 18. When the signals are transformed, total image area 94 of CCD 74,  
30 which is typically small compared to the size of monitor 18, proportionately corresponds to image area 58 of monitor 18. The active image area 96 of CCD 74 corresponds to a displayed image area 60 of monitor 18, and both areas 60, 96

represent the actual image area that is produced by  
endoscope 20. Similarly, the inactive image area 98  
corresponds to a darkened border area 62 of monitor 18, and  
both inactive image areas 62, 98 represent image areas that  
5 lie outside the actual image area that is produced by  
endoscope 20.

In typical monitors, the total image area 94 of CCD  
74 roughly corresponds to total image area 58 of the  
monitor, but the relation is not exact. The portion of  
10 total image area 94 of CCD 74 that is actually displayed  
within total image area 58 of the monitor is different for  
different types of monitors. For example, the total image  
area of a typical monitor includes slightly more than total  
image area 94 of CCD 74. Many currently available monitors  
15 contain an "underscan" feature that, when selected,  
incorporates a larger area than total image area 94 of CCD  
74 into the total image area of the monitor. However, for  
purposes of example, total image area 58 of monitor 18  
displays exactly all of total image area 94 of CCD 74.

20 The entire image of total image area 94 of CCD 74,  
i.e., both the actual image area of active image 96 and the  
dark area of inactive image area 98, is incorporated into  
the fully processed video signal. The electrical signals  
generated by the photoelectric cells outside the active  
25 image area 96 have a relatively low signal level. On the  
other hand, the electrical signals generated by the  
photoelectric cells within active image area 96 where light  
is incident on the cell have a relatively larger signal  
level. Processor 82 incorporates the various signal levels  
30 into the fully processed video signal.

However, operating alone, processor 82 may not  
properly control the brightness of visual image 56 without  
additional controls, such as automated control signals from

image size detection circuit 75 or manual input from an operator. If image size detection circuit 75, which provides an automated control signal, is absent from system 10, the displayed image area 60 may be washed-out or glared.

5 This is because electronic shutter 72 is generally responsive to the electrical signals provided by the "entire" CCD (i.e., all photoelectric cells on total image area 94). Inactive area 98 can cause electronic shutter 72 to, in a sense, inadequately respond such that the light  
10 exposure of CCD 74 is too large. As a result, images displayed in active image area 60 of monitor 18 may be washed-out or glared. Indeed, as inactive area 94 becomes relatively larger, for example, when zoom lens assembly 36 is zoomed out, the image of active image area 60 is more  
15 likely to be washed-out or glared.

As discussed above, when the physician manipulates zoom lens coupler 24, the active image area 96 becomes larger or smaller. The proportion of active image area 96 changes relative to inactive area 98 because the size of the  
20 active image area changes relative to the total image area 94. Therefore, electronic shutter 72 may respond differently to the increase, or decrease, in the size of inactive image area 98, even though the brightness of active image area 96 may not have changed. Thus, although electronic shutter 72  
25 could inadequately respond to an image produced by any medical viewing instrument, zoom coupler 24 can accentuate the problem of excessive brightness.

Some existing cameras may partially compensate for inadequate electronic shutter response by allowing an  
30 operator to select a electronic shutter response area that, in essence, electronically masks most or all of the inactive image area from the electronic shutter. However, such cameras do not dynamically adjust to changes in the size of

the actual image. In addition, if the selected shutter response pattern is too small and directs the electronic shutter to respond to only a small portion of the actual image, changes in that small portion can affect the  
5 brightness of the overall actual image even if the brightness of the remainder of the actual image is sufficient. For example, if the small portion becomes brighter while the remainder of the actual image remains at approximately the same level of brightness, the overall  
10 image may appear too dark as the electronic shutter attempts to reduce the brightness of the small portion of the actual image. On the other hand, if the small portion becomes darker while the remainder of the actual image remains at approximately the same level of brightness, the overall  
15 image may appear too bright as the electronic shutter attempts to increase the brightness of the small portion of the actual image.

To eliminate the effect of darkened image area 98 on electronic shutter 72 and allow the electronic shutter to  
20 adequately respond to the overall image, image size detection circuit 75 recognizes that only a portion of image area 94 may be occupied by active image area 96. In particular, image size detection circuit 75 determines the approximate size of active image area 96 so that electronic  
25 shutter 72 can respond predominately to the level of brightness of active image area 96 while ignoring inactive image area 98.

Image size detection circuit 75 uses the luminance video signal component provided by processor 82 to generate  
30 electronic control signals that allow electronic shutter 72 to better control the brightness of visual image 56. The luminance video signal component is received from processor 82 by image size detection circuit 75 along analog signal

line 76. Image size detection circuit 75 and processor 82 are connected in a feedback arrangement, in which the luminance video signal component is transmitted from processor 82 to image size detection circuit 75. In response to the horizontal image duration of the luminance video signal component, image size detection circuit 75 generates electronic control signals (e.g., digital words) to control electronic shutter 72.

Referring to FIGS. 3a-3d, in response to the video signal from CCD 74, the image size detection circuit 75 selects one of five predetermined electronic shutter response areas 64a-64e stored in processor 82: a medium electronic shutter response area 64a, a small electronic shutter response area 64b, a large electronic shutter response area 64c, a central electronic shutter response area 64d, and an all-electronic shutter response area 64e (i.e., all of the total image area 94). Each of electronic shutter response areas 64a-64e corresponds to a range of actual image areas. Image size detection circuit 75 selects one of electronic shutter response areas 64a-64e as an approximation of a given active image area 96 of CCD 74. The selected electronic shutter response area 64a-64e defines the portion of total image area 94 to which electronic shutter 72 will respond when regulating the level of brightness of active image area 96.

For example, if image size detection circuit 75 determines that active image area 96a (shown in FIG. 3a) is the actual image area, image size detection circuit 75 selects a predetermined medium electronic shutter response area 64a. Medium electronic shutter response area 64a is the area of total image area 94 to which electronic shutter 72 will respond when adjusting the light exposure of active image area 96a. Similarly, if image size detection circuit

75 determines that active image area 96b (shown in FIG. 3b) is the actual image area, image size detection circuit 75 selects a predetermined small electronic shutter response area 64b. Small electronic shutter response area 64b is the area of total image area 94 to which electronic shutter 72 will respond when adjusting the light exposure of image area 96b. Image size detection circuit 75 follows a similar process to select large, central, and all electronic shutter response areas 64c-64d.

In the present embodiment, the actual image generally received by endoscope 20 and zoom coupler 24 is a circular image incident on CCD 74. Therefore, image size detection circuit 75 is designed with the assumption that the shape of active image area 96 has a circular shape and that the position of the origin of active image area 96 is at the center of total image area 94. Based on this assumption, image size detection circuit 75 needs to determine only the area of active image area 96. To do so, image size detection circuit 75 examines the luminance video signal component to determine a combined average of the horizontal image durations over a predetermined period of time. The luminance video signal component has a higher horizontal image duration for larger active image areas than for smaller active image areas. In other words, the duration of the luminance video signal component for one full display screen will be larger for larger active images, and the duration of the luminance video signal component for one full display screen will be smaller for smaller active images. The horizontal image duration in the luminance video signal component for each full screen of the video image is proportional to the size of the active image area 94. Image size detection circuit 75 utilizes this

proportional relationship to determine the size of active image area 96.

Referring to FIG. 4, image size detection circuit 75 includes a comparator 84, an integrator 86, an analog to digital converter (A/D converter) 88, and a lookup table 90. Image size detection circuit 75 also utilizes a random access memory (RAM) 92 that is physically located in processor 92. Comparator 84 receives the luminance video signal component from processor 82 and generates a series of pulses when the signal level of the luminance signal component is greater than a predetermined threshold. The pulses represent the length of active image present on each horizontal line of the total image area 94. For example, when comparator 84 processes an electronic signal representing a horizontal line that extends through only inactive image area 98, e.g., the top line of total image area 94, the comparator outputs a logical "0" for the entire duration of time that the horizontal line is processed. However, when comparator 84 processes an electronic signal representing another horizontal line that extends through both inactive image area 98 and active image area 96, e.g., the center line of total image area 94, the comparator transitions from a logical "0" to a logical "1" at the leading edge of active image area 96 and transitions back to a logical "0" at the trailing edge of active image area 98.

Integrator 86 receives the series of pulses from comparator 86 and integrates the pulses to produce a DC voltage level output. The DC voltage level is proportional to the total duration of the positive pulses from comparator 84. In essence, the output of integrator 86 represents the area of the actual image present in one video screen, i.e., a snapshot of the actual image area within total image area 94.

A/D converter 88 receives the DC voltage output from integrator 86 and converts the DC voltage output into a digital word received by lookup table 90. Lookup table 90 converts a range of digital input words into a corresponding one of five digital output words, for example, 00 hex to 04 hex. Thus, one continuous range of voltage levels from integrator 86 corresponds to one of the digital output words, e.g., "00" hex, and the next continuous range of video output signal levels corresponds to the next consecutive digital output word, e.g., "01" hex, etc..

The image size detection circuit 75 transfers the selected digital output words to a photometric area address in RAM 92 that processor 82 periodically and regularly examines so that the processor can retrieve the selected electronic shutter response pattern 64a-64e. It is important to note that the determination of image size is continuous rather than periodic or synchronized to distinct video frames. Thus, image size detection circuit 75 may send data to the photometric area address of processor 82 based on both electronic signals representing a latter portion of one video screen and electronic signals representing a beginning portion of a following video screen.

Each electronic shutter response area 64a-64e is an approximation of active image area 96 that electronically masks all or most of inactive image area 98 from electronic shutter 72. Therefore, electronic shutter 72 optimizes the brightness of active image area 96 by responding predominately to active image area 96.

Image size detection circuit 75 operates in real-time to dynamically and automatically select an appropriate electronic shutter response area 64a-64e on the basis of the analog video signal received from camera head 44. In



particular, image size detection circuit 75 determines the portion of total image area 94 of CCD 74 receiving the actual image provided by endoscope 20 (i.e., the active image area 96). Based on the determination, image size  
 5 detection circuit 75 selects one electronic shutter response area 64a-64e that approximates the size of the actual image. As the size of active image area 96 changes, image size detection circuit 75, which is continuously determining the size of active image area 96, detects the new size of the  
 10 image and automatically selects the appropriate shutter response 64a-64e according to the predefined algorithm.

Referring also to FIG. 5, image size detection circuit 75 continuously operates according to an algorithm 100 that selects one of the five shutter response areas  
 15 stored in RAM area 92 in processor 82. If the actual image area is relatively small, image size detection circuit 75 selects a relatively small shutter response area from the five prestored electronic shutter response patterns 64a-64e in RAM 92. If the actual image area is large, image size  
 20 detection circuit selects a relatively large shutter response area from the five prestored electronic shutter response patterns 64a-64e in RAM 92. Image size detection circuit 75 proceeds sequentially through the steps 102, 106, 110, 114, and 118 of algorithm 100 to select, according to  
 25 corresponding steps 104, 108, 112, 116, and 120, the most appropriate electronic shutter response area 64a-64e for a particular actual image. Each successive step 102, 106, 110, 114, and 118, corresponds to progressively larger actual image areas.

30 For example, if the size of a particular actual image area corresponds to a predefined range of digitized input words produced by A/D converter 88, e.g., "5E" hex - "7C" hex as in step 106, image size detection circuit 75

5 sends data, e.g., "02" hex, representing the appropriate electronic shutter response area, e.g., medium electronic shutter response area 64a, to the photometric area address of RAM 92. If the size of the particular actual image area does not correspond to the range of digitized input words, the image size detection circuit 75 proceeds to the next sequential step of algorithm 100.

10 Image size detection circuit 75 produces a reasonably accurate measurement of the size of active image area 96, but the measurement is not exact. However, image size detection circuit 75 quickly and accurately determines the size of active image area 96 by integrating an average of the total amount of time, within a predetermined  
15 timeframe, that the signal for each total image area 94 represents as an actual image. Thus, image size detection circuit 75 allows system 10 to minimize system delays and to incorporate, and be compatible with, existing off-the-shelf components. Alternatively, image size detection circuit 75 can further improve (or degrade) the performance of  
20 electronic shutter 72 by selecting more (or less) accurate approximations of active image area 96 or by having lesser (or greater) amounts of delay in system 10.

However, other embodiments are within the scope of the invention.

25 For example, the embodiment described above approximates the size of active image area 96 and presumes that the image is located in the center of total image area 94. However, other embodiments could measure exactly the size and shape or position of active image area 96. In  
30 addition, such embodiments could combine the position and size measurements and select an appropriate electronic shutter response area 64a-64e having a position offset to more optimally control the brightness of active image area

96. Such embodiments may require additional logic that could increase delay in the system or that could require additional components to maintain system performance, such as a microprocessor having sufficient speed and memory.

5 In other embodiments, the image size detection circuit could calculate the size and position of active image area 96 and use active image area 96 to formulate an exact electronic shutter response area rather than selecting a predetermined electronic shutter response area 64a-64e.

10 The image size detection circuit and the processor could be an integrated unit or a device could be constructed of a number of different components. The RAM area could be physically located within the image size detection circuit. The image size detection circuit could be implemented using  
15 a microprocessor, integrated circuits, analog components, software, firmware, or a combination of these or other implementations. The image size detection circuit could process the fully processed video input signal. The image size detection circuit could incorporate additional  
20 electronic shutter response areas or an entirely different set of electronic shutter response areas stored in the RAM area.

A camera which allows an operator to create and store predetermined electronic shutter response areas in the  
25 RAM area of the camera could be used. In addition, shutter response patterns could be created in real time to allow specific applications, for example, a single display having multiple actual images and a different electronic shutter response area associated with each image.

30 The system can include optical couplers, endoscopes, and cameras that do not have a zoom lens assembly or any other zoom capability. The system can include many different medical viewing instruments, e.g, colonoscopes or

borescopes, and many different coupler combinations including no coupling, no zoom coupling, or a medical viewing instrument having an integrated coupler. The system can include different types of shutters such as shutters  
5 having adjustable apertures or rotating drum shutters. The system can include different types of image sensors, for example, CMOS image sensors.

It will be appreciated by one skilled in the art that many additional and different components and many  
10 additional and different configurations other than those described herein could be used without departing from the scope of the following claims.

What is claimed is: